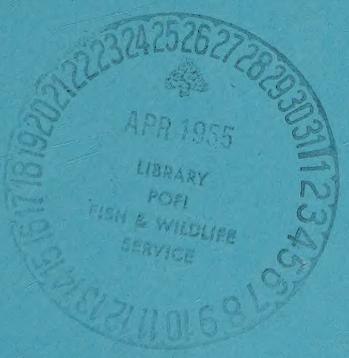
Marine Research

SCOTTISH HOME DEPARTMENT

Marine Research
1952 No. 3

The Food of Halibut from North Atlantic Fishing Grounds

By A. D. McINTYRE, B.Sc.



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'he Food of Halibut from North Atlantic Fishing Grounds

INTRODUCTION

The food and feeding habits of fish, particularly those of commercial importance, have been tensively studied. But considering the importance of the North Atlantic halibut, our knowledge of biology and food is slight.

Scott (1909) studied 1,076 halibut stomachs from unspecified areas in the North Sea and North lantic. His material was examined unpreserved after landing and a considerable amount of deterior- on must have taken place. Beyond quoting numbers of stomachs containing certain species, Scott ɔstly confines himself to general statements such as "crustacea were tolerably frequent." He concludes at fish, mostly haddock and whiting, form a considerable part of the diet, particularly in the case the larger halibut, while among crustacea, *Nephrops norvegicus* and Eupagurids were of frequent currence.

Todd (1905) found fish, crustaceans, and molluscs in one halibut stomach from the North Sea. persen (1926) examined 204 halibut trawled in Faxa Bay in June. Only age groups II and III were died; although no detailed analysis was made, the smaller specimens were found to feed mainly on ustacea, and the larger ones on fish. Lovern and Sharp (1933) found that the food was very varied, d suggested that halibut "ate anything they could get." Dr. B. B. Rae (unpublished work) examined specimens from the North Sea and 61 from Faroe. 71% of the stomachs contained fish, 39% crustacea, d 9% molluscs. He noted that as the halibut grows the proportion of crustacea in its diet diminishes, d the proportion of fish increases.

ACKNOWLEDGMENTS

This work could not have been carried out without the assistance of many Aberdeen long-line ıermen who collected and preserved samples of stomachs. I wish to thank the owners, skippers, d crews of the following Aberdeen steam liners:— *Ben Roy, Confederate, Kinellar, Kinord, Loch Laggan, :h Lee, Mount Keen, Onetos, Ocean Eddy,* and *River Ayr.* Special thanks are due to Skipper A. Morrice, the motor-liner *Clamor,* not only for collecting stomachs, but also for allowing me to be present on o voyages to the Iceland fishing grounds.

MATERIAL AND METHODS

One thousand two hundred and twenty-five halibut stomachs were examined, comprising 630 m Iceland, 513 from Faroe, 64 from West of Scotland, 13 from the North Sea and 5 from Newfound- ıd. The Scottish research vessels, *Explorer* and *Scotia,* collected 135 of the stomachs, but most of the ıterial was taken from the catches of commercial long-line fishing vessels working from Aberdeen. ɔmachs were collected from commercial vessels in large milk cans containing formalin. These were ıced on selected vessels, and skippers were asked to fill the cans with guts from one day's fishing. The ıermen were to make no selection of guts and no discrimination between large and small, full and pty. The first stomach having been preserved, all succeeding stomachs were to be collected until : can was full. It was hoped thus to secure a random sample of the catch. The mouths of cans were a diameter great enough to take the largest halibut stomach, thus obviating the bias of size selection ted by Brown and Cheng (1946) who used a somewhat similar method for collection of cod stomachs. ippers of vessels were asked to note date, depth, and position at which guts were collected, and to ıke any other relevant comments.

This method of collection involves several possible sources of error. Fish were caught chiefly by ing, a method which may introduce selective sampling, since the taking of bait is probably influenced the physiological state of the fish, and thus also by environmental conditions. This is discussed on ge 19 and at this juncture it is necessary to note only that in the areas studied no gear other than es provided adequate samples of mature fish. Another possibility of bias arises from the fact that nmercial vessels try to operate where fish are most dense.

Fishermen were always helpful in supplying information, but it was obviously not possible to obtai measurements of the fish from which stomachs were taken. However, from research vessel data, an from measurements made by the writer during trips on commercial vessels, it was found that the tot length of fish could be estimated from the length of the first pyloric caecum. The estimates were, course, approximate, but they allowed the guts to be allocated to particular size-groups of fish. Fou size groups were distinguished according to the following table:—

Group reference	Size of first pyloric caecum	Estimated age of fish	Estimated length of fish
A	<3·1 cms.	up to 2 years	<31 cms.
B	3·1- 6·0 cms.	2-4 years	31-60 cms.
C	6·1-10·0 cms.	5-9 years	61-90 cms.
D	>10·0 cms.	more than 9 years	more than 90 cms.

There are many ways of presenting data on fish food. The numerical method, showing the numbe of an organism in each stomach, or the numbers of stomachs containing the organism, may be misleadi when large and small food species are present together. When the numerical method was used, previo investigators (see Hardy 1924 and Hynes 1950) sometimes weighted the numbers of larger organisr according to their bulk. Russian workers (Bogorov *et al.*, 1939) insisted that results should be expresse by weight. The weight or volume method, however, may give undue importance to large organisr occurring infrequently. No one method of expression is entirely satisfactory. In the present pap the data are presented in three ways. First the number of stomachs containing each group is expresse as a percentage of the total stomachs containing food. This is referred to as percentage occurren Second, the volume of each food group, measured by water displacement, is expressed as a percenta of the total volume of all food. Third, the average volume per stomach, based on the number of stomac containing the group in question, is recorded. By examing the data in these three forms, it is possi to arrive at a fairly accurate estimate of the proportions of food in the stomachs.

THE FOOD OF THE HALIBUT OFF ICELAND

Composition of the Food

The material from Icelandic waters consists of 590 stomachs (24 samples) collected by commerc vessels, and 40 stomachs (2 samples) collected by F.R.S. *Scotia*. Table I gives the dates of the voyag the positions from which samples were taken, and the number of stomachs collected. Most of t samples were from fishing grounds off the west coast at depths between 100 and 300 fathoms, whe the halibut catch of Aberdeen long line vessels is composed of large fish mostly over 90 cms. long.

Of the 630 stomachs examined, 310 contained food. The distribution of the stomachs in the s groups described on page 3 is as follows:—

Estimated size group	Group A <31 cms.	Group B 31-60 cms.	Group C 61-90 cms.	Group D >90 cms.	Total
Empty stomachs (with % in brackets)	0(0%)	15(68%)	151(73%)	154(41%)	320(51%
Stomachs containing food	33	7	57	213	310
Total =	33	22	208	367	630

The data on the main constituents of the diet of each size group are summarised in Fig. 1.

ICELAND

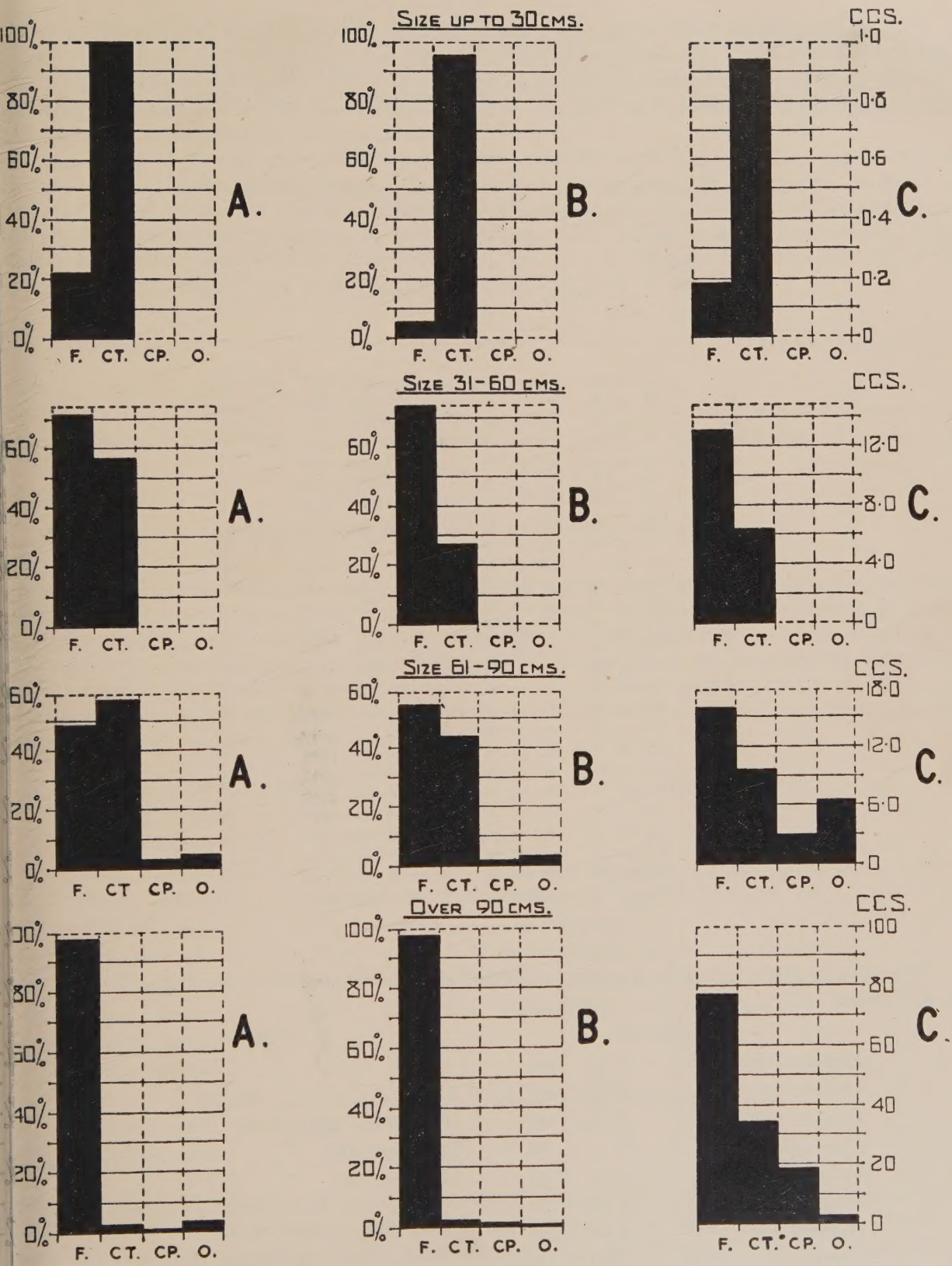


FIG. 1.—Stomach contents of Iceland halibut.
A — denotes percentage occurrence of each food group.
B — denotes percentage of total volume contributed by each group.
C — denotes average volume per stomach containing this food.
F = Fish. CT = Crustacea. CP = Cephalopoda. O = Other food.

The 33 individuals of size group A (< 31 cms.), were collected in September, 1950, by F.R.S. *Scotia* in two trawl hauls, one made inside Faxa Bay, and the other 8 miles N.W. of Reykjanes. All the stomachs were well filled and all contained crustacean remains, the average volume of which was 0·95 ccs. Traces of fish (average volume 0·18 ccs.) were present in eight stomachs.

TABLE I

The dates of voyages to Iceland, the numbers of stomachs collected, and the approximate positions from which they were taken.

Voyage	Position		Date	No. of stomachs
A	63° 45′ N	14° 40′ W	December 1948	29
B	64° 40′ N	24° 50′ W	February 1949	55
C	63° 25′ N	22° 05′ W	February 1950	17
D	65° 23′ N	27° 20′ W	February 1950	20
E	65° 08′ N	24° 40′ W	March 1949	63
F	64° 45′ N	25° 55′ W	March 1949	33
G	63° 00′ N	21° 40′ W	March 1949	12
H	63° 10′ N	23° 10′ W	March 1950	18
I	64° 32′ N	25° 20′ W	April 1949	32
J	64° 50′ N	26° 42′ W	May 1949	13
K	64° 23′ N	26° 45′ W	May 1950	17
L	65° 03′ N	27° 20′ W	May 1950	26
M	65° 03′ N	27° 20′ W	May 1950	21
N	64° 02′ N	27° 25′ W	May 1950	21
O	65° 03′ N	27° 20′ W	May 1950	28
P	65° 18′ N	27° 12′ W	June 1949	15
Q	65° 20′ N	27° 18′ W	June 1949	13
R	63° 15′ N	24° 55′ W	June 1949	20
S	65° 08′ N	27° 28′ W	June 1949	16
T	63° 27′ N	25° 10′ W	August 1949	24
U	63° 37′ N	25° 05′ W	August 1949	26
V	63° 37′ N	25° 05′ W	August 1950	22
W	64° 03′ N	22° 33′ W	September 1950	35
X	63° 52′ N	22° 58′ W	September 1950	5
Y	63° 15′ N	20° 40′ W	October 1949	12
Z	65° 24′ N	28° 20′ W	November 1950	37

The volumes of the various food groups, expressed as proportions of the total volume in the stomachs are as follows:—

CRUSTACEA			FISH		
Eupagurus spp.	0·30	(19)			
Portunus spp.	0·25	(23)			
Pandalus spp.	0·16	(10)	*Hippoglossus hippoglossus*	0·01	(2)
Hyas spp.	0·12	(8)	Pleuronectidæ	0·01	(1)
Galathea spp.	0·09	(4)	Fish remains	0·02	(5)
Mysid	0·02	(1)			
Hippolytidæ	0·01	(3)			
Crustacean remains	0·01	(1)			

(The numbers in brackets represent the numbers of stomachs in which the various groups occurred).

The 22 stomachs in size group B (31-60 cms.) were contained in three trawl samples, one from xa Bay (September), one from 8 miles north-west of Reykjanes (September) and one from 24 miles st of Snaefieldsjokull (February). Only seven of the stomachs contained food, and of these, fish (ling d whiting) occurred in five with an average volume of 12·5 ccs., and crustacea (Nephrops, Pandalus d Eupagurids) in four with an average volume of 6·2 ccs.

In size group C (61-90 cms.) 208 stomachs were collected, mostly during winter and spring, in samples from commercial line vessels. Food was found in 57 stomachs (27%) and of these, 34 ·6%) contained crustacean remains, and 28 (49·1%) contained fish. Cephalopod remains were sent in one stomach and unidentifiable material in two. The average volumes per stomach of fish, stacea, and cephalopoda were 16·0 ccs., 10·4 ccs., and 3·0 ccs., respectively. The volumes of the ious food groups, expressed as proportions of the total food were as follows:—

CRUSTACEAN			FISH			OTHER GROUPS		
hrops norvegicus	0·34	(18)	*Sebastes marinus*	0·13	(2)			
dalus spp.	0·07	(7)	*Brosme brosme*	0·02	(2)	Cephalopoda	>0·01	(1)
ıstacean remains	0·02	(9)	*Gadus aeglefinus*	0·01	(1)	Remainder	0·02	(2)
			Gadus minutus	<0·01	(2)			
			Fish remains	0·10	(16)			

(The numbers in brackets represent the numbers of stomachs in which the various groups occurred).

Most of the stomachs belonged to size category D (fish over 90 cms. long) and were collected chiefly pring and summer, in 24 samples from commercial vessels. 367 stomachs were examined in this ıp and 213 (58%) contained food. Of these 209 (98·1%) contained fish, 4 (1·8%) crustacea, 1 ıalopod, and 3 contained other groups. The great predominance of fish as shown by occurrence lso illustrated by the average volumes per stomach—76·6 ccs., 34·5 ccs., 19·4 ccs., and 2·3 ccs. for crustacea, cephalopoda and other groups respectively. The volumes of the various species expressed ercentages of the total food volume are as follows:—

FISH			OTHER GROUPS		
Sebastes marinus	77·11	(122)			
Brosme brosme	6·88	(7)			
Gadus aeglifinus	3·69	(5)	*Nephrops norvegicus*	0·65	(2)
Molva byrklange	1·66	(4)	Crustacean remains	<0·01	(2)
Clupea harengus	0·52	(5)	Cephalopoda	0·09	(1)
Argentina spp.	0·11	(5)	*Pseudoarchaster Parelii*	0·01	(1)
Skate egg case	0·06	(1)	Invertebrate remains	0·02	(1)
Gadus minutus	<0·01	(1)	Unidentified remains	<0·01	(1)
Gadoid remains	0·02	(4)			
Fish remains	9·16	(73)			

(The numbers in brackets show the numbers of stomachs in which each group occurred).

A Variations

The fishing grounds off the west and south coasts of Iceland cover a very large area, and samples often taken from widely separated positions. In considering the possibility that this area difference give rise to a difference in feeding we shall eliminate bias due to age or seasonal differences by ıing fish of the same age group caught in the same season. Since fish of size group D formed the ır part of the catches we will confine ourself to these.

Of eleven samples taken in spring, the stomachs in eight contained only fish, and in the remain three samples the volume of non-fish material was less than 1% of the total food. Of the identifia fish, *Sebastes marinus* formed an average of 88% per sample by volume, the range over all samples be 61-100%.

In summer six samples were taken, and the stomachs contained only fish. In five of the samp the fish remains consisted entirely of Sebastes, and in the sixth sample, although haddock, tusk and b ling were also present, Sebastes made up 61% of total food.

Thus, for the largest fish at least, there appears to be no significant difference in food between various areas sampled off Iceland. Evidence for the smaller size-groups is less reliable, but there no obvious signs of area differences in feeding.

Seasonal Variations

Sufficient stomachs have been obtained in size groups C and D to allow of a comparison betwe seasons.

In group C, four samples were collected in winter and four in spring. The average percenta of empty stomachs per sample was $52 \cdot 3 \pm 13 \cdot 3\%$ in winter, and $82 \cdot 9 \pm 8 \cdot 8\%$ in spring—a seaso difference which is not significant at the 5% or 1% levels.

Fig. 2 compares the percentages of the various food groups in winter and spring. It indicates importance of *Nephrops norvegicus* in winter and herring in spring.

In size group D, 11 samples (177 stomachs) were taken in spring and 7 (125 stomachs) in summ The average percentage of empty stomachs was $50 \cdot 6 \pm 4 \cdot 2\%$ in spring and $31 \cdot 8 \pm 7 \cdot 8\%$ in summ These show a difference which is just significant at the 5% level and suggest a period of more intens feeding in summer. Fig. 3 shows the relative importance of the various species in each season. *Seba marinus* formed the major part of the food throughout the whole year, but tusk was consumed in so quantity in spring and autumn, and *Nephrops norvegicus* in winter.

Thus there are probably fairly important seasonal differences within these two groups and th may well extend to the smaller sizes.

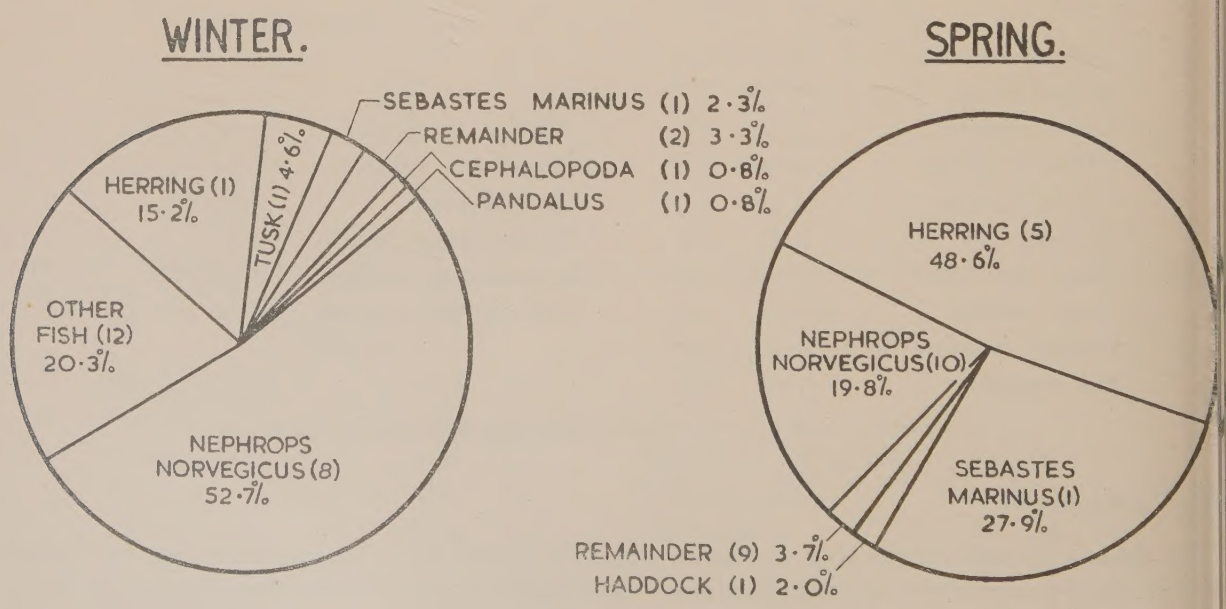
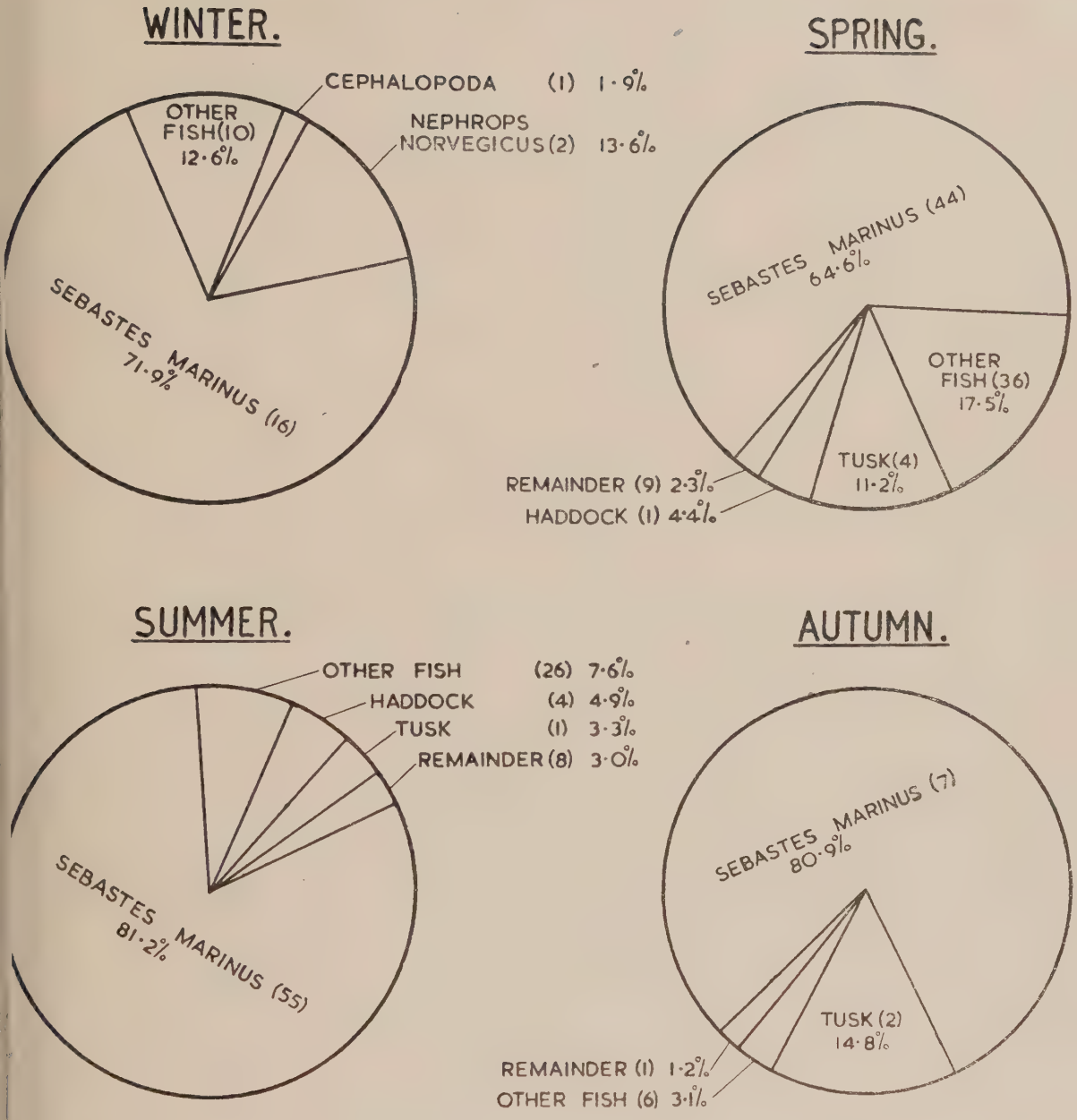


Fig. 2—Seasonal changes in the stomach contents of Iceland halibut of size group C (61-90 cms.). The volumes of the various c stituents of the diet are expressed as percentages of the total food volume in winter (left) and spring (right). The numbe stomachs in which each food group occurred is shown in brackets.



3—Seasonal changes in stomach contents of Iceland halibut of size group D (>90 cms.). The volumes of the various constituents of the diet are expressed as percentages of the total food volume in each season. The number of stomachs in which each food group occurred is shown in brackets.

TABLE II

The dates and position of samples from Faroe

Size group	Date	Area	No. of stomachs
A	March 1950	YY23	1
	March 1950	XX24	2
	August 1950	XX23	2
	November 1949	WW23	1
B	March 1950	VV20-21	222
	March 1949	WW23	3
	March 1950	XX23	3
	March 1950	YY23	1
	April 1949	VV20-21	74
	April 1950	VV20-21	58
	April 1950	WW22	4
	April 1950	WW23	5
	April 1950	XX22	1
	April 1950	XX23	3
	April 1950	ZZ23	1
	May 1949	RR19-20	79
	May 1950	VV23	1
	May 1949	WW22	1
	May 1949	XX22	3
	May 1949	XX23	1
	May 1949	XX24	1
	May 1949	YY23	2
	May 1950	WW23	1
	June 1950	XX24	7
	July 1949	XX20	1
	July 1949	XX21	1
	July 1950	XX21	3
	July 1950	XX23	1
	July 1951	XX23	16
	July 1951	XX24	1
	July 1950	WW22	1
	July 1950	WW24	1
	August 1950	XX23	3
	September 1949	VV20	1
	September 1950	WW22	1
	November 1949	WW23	1
C	May 1949	XX21	1
	June 1950	VV20	1
	July 1950	XX21	1
	July 1951	XX23	1
	July 1950	YY23	1

THE FOOD OF THE HALIBUT OFF FAROE

Composition of the Food

From the Faroe area, five samples, comprising 433 stomachs were obtained by commercial vess and 80 stomachs were collected in 22 trawl hauls by *Scotia* and 23 hauls by *Explorer*. The dates of cru

id the sampling positions are shown in Table II. The distribution of the guts in size groups is as lows:—

Estimated size group	Group A <31 cms.	Group B 31-60 cms.	Group C 61-90 cms.	Group D >90 cms.	Total
npty stomachs (with % in brackets)	0(0%)	16(19%)	144(46%)	48(43%)	208(41%)
omachs containing food	6	68	167	64	305
Total =	6	84	311	112	513

Halibut caught off Faroe are smaller than those from Iceland, and the greater part (63%) of the machs belong to group C.

Six group A specimens were obtained by trawl and the stomachs of five of these contained crustacea, th an average volume of 0·94 cms. The genera represented were Pandalus, Portunus, and Eupagurus, d their proportions by volume were 3 : 2 : 1 respectively. Three of the stomachs also contained 1 (Ammodytes, and young halibut). The average volume being 1·5 ccs. The proportions of stacea and fish in the total food volume were 0·51 and 0·49 respectively.

The data on the larger size categories are summarised by histograms in Fig. 4.

In group B, 84 specimens were obtained, of which 69 were taken by trawl from research vessels. ain fish and crustacea predominated, fish occurring in 40 stomachs and crustacea in 50. By volume, wever, there was considerably more fish than crustacea, the average volume of the former being . ccs. and of the latter 5·6 ccs. Remains of the cephalopod *Moschites cirrosa* were found in only two machs but the average volume, 9·8 ccs. was high, and this species represented 1·4% of the total food. zozoans were the only other organisms present, and these occurred in one stomach, with a volume 0·2 ccs.

The volumes of the various species expressed as percentages of the total food are as follows:—

CRUSTACEA		FISH		OTHER GROUPS	
agurus spp.	24·13 (27)	*Ammodytes spp*	15·91 (16)		
tunus spp.	5·65 (11)	*Gadus aeglifinus*	8·26 (1)		
idalus spp.	4·31 (15)	*Gadus merlangus*	4·35 (1)		
nida spp.	1·83 (4)	*Gadus esmarkii*	3·39 (2)	*Moschites cirrosa*	2·88 (2)
s coarctatus	1·68 (5)	*Gadus minutus*	1·84 (1)	Bryozoa	0·03 (1)
athea spp.	0·37 (1)	Gadoid remains	2·95 (4)		
capod crustaceans	0·22 (2)	*Callionymus spp.*	0·27 (1)		
stacean remains	3·12 (6)	*Pholis gunnellus*	0·29 (1)		
		Fish remains	18·33 (16)		

(The figures in brackets show the number of stomachs in which each group occurred).

FAROE

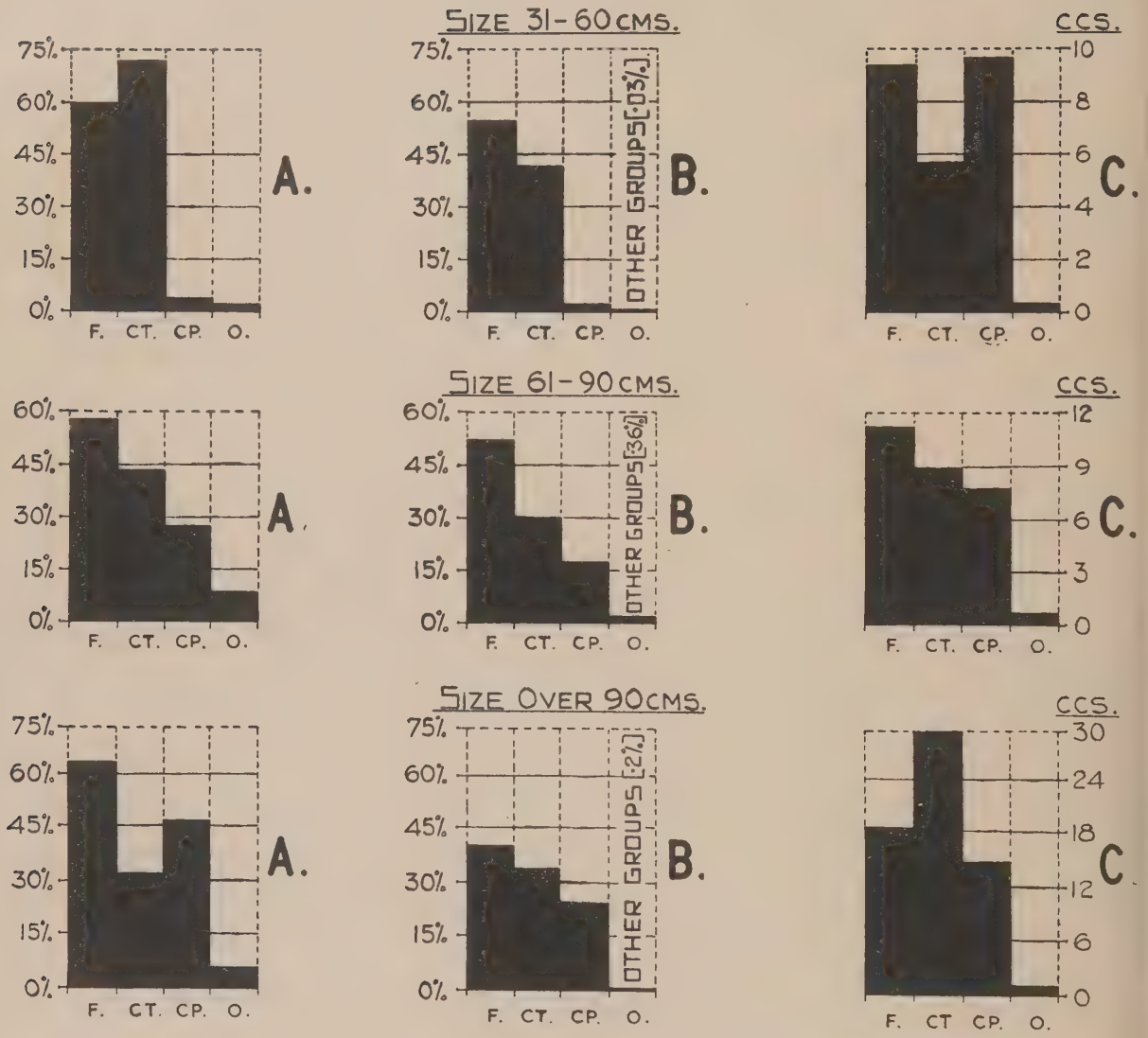


FIG. 4—Stomach contents of Faroe halibut.
A — denotes percentage occurrence of each food group.
B — denotes percentage of total volume contributed by each group.
C — denotes average volume per stomach containing this food.
F = Fish. CT = Crustacea. CP = Cephalopod. O = Other food.

Group C contained the majority of Faroese fish, and 311 stomachs from this size category were examined. Most of these were collected by commercial line vessels and 167 stomachs (54%) contained food. The percentage occurrence of the main food groups, and their average volumes per stomach are as follows:—

	FISH	CRUSTACEA	CEPHALOPODA	OTHER GROUPS
% occurrence ..	58%	43%	28%	8%
average volume ..	11·6 ccs.	9·0 ccs.	7·8 ccs.	0·5 ccs.

Again, fish and crustacea occur in greatest quantity, with the former predominating. The increase in importance of cephalopoda, however, should be noted. The percentages of the total food volume

presented by fish, crustacea and cephalopoda were 53%, 30% and 17% respectively. The quantity material of other groups was negligible. The percentages which the various groups formed of the al volume were as follows:—

FISH			CRUSTACEA			OTHER GROUPS		
h remains	20·09	(49)	*Munida spp.*	11·14	(19)	Cephalopod remains	9·83	(37)
dus aeglifinus	10·07	(3)	*Munida bamffica*	1·08	(2)	*Moschites cirrosa*	4·39	(3)
pea harengus	9·41	(7)	*Lithodes maia*	6·12	(7)	Octopod remains	2·48	(1)
astes marinus	5·42	(2)	*Atelecyclus spp.*	3·49	(9)	*Rossia glaucopis*	0·65	(1)
uronectes limanda	2·97	(1)	*Hyas coarctatus*	1·94	(4)	Remainder	0·34	(14)
dus minutus	1·68	(3)	*Eupagurus bernhardus*	1·10	(2)			
modytes spp.	1·40	(2)	*Eupagurus spp.*	0·81	(3)			
Ilionymus spp.	1·22	(3)	*Galathea spp.*	1·59	(10)			
npenus spp.	0·37	(1)	*Portunus spp.*	0·61	(2)			
doid remains	0·09	(1)	Decapod crustacea	0·37	(1)			
			Crustacean remains	1·43	(26)			

(The figures in brackets show the number of stomachs in which each group occurred).

Material for group D, the largest size category, was obtained only by commercial vessels. A total 12 stomachs were examined, and of these 64 (57%) contained food. The percentage occurrence of fish, halopoda, crustacea, and other groups was 64·1%, 46·9%, 32·8%, and 6·3% respectively, and the centages which each of these food groups represented of the total volume were 41·1%, 24·6%, 34·1% l 0·2% in the same order. Fish thus occurred in a great number of stomachs, and its total volume greater than that of any other group. The average volumes per stomach were 18·8 ccs. (fish), 4 ccs. (cephalopoda), 30·5 ccs. (crustacea), and 1·1 ccs. (other groups). The high value for crustacea ue to the presence in a few stomachs of very large specimens of *Lithodes maia*. In general, then, for size group, fish again predominates. Cephalopoda are present in a greater number of stomachs n crustacea, but the average volume is smaller. This is probably due to faster digestion of the soft ied cephalopoda, and it is difficult to decide which of these two groups is of greater importance to halibut. The percentages which each species represented of the total food volume are as follows : —

FISH			CRUSTACEA			OTHER GROUPS		
n remains	30·24	(32)	Crustacean remains	0·60	(7)	Cephalopod remains	14·11	(25)
us aeglifinus	5·05	(3)	*Lithodes maia*	31·71	(8)	Octopod remains	3·17	(2)
stes marinus	2·82	(1)	*Munida spp.*	0·32	(1)	*Moschites cirrosa*	7·34	(3)
ea harengus	2·51	(2)	*Galathea spp.*	1·25	(3)	*Emarginula mulleri*	<0·01	(1)
nodytes spp.	0·27	(1)	*Atelecyclus spp.*	0·03	(1)	Gastropoda	0·19	(1)
us minutus	0·20	(2)	Decapod crustacea	0·16	(1)	Remainder	0·03	(1)

(The figures in brackets show the number of stomachs in which each group occurred).

SONAL VARIATIONS

Since the material from Faroe was collected from the same stations in each season, the seasonal ations in feeding may be studied without bias due to area differences. Size category B is represented ufficient numbers in spring and summer for such a seasonal comparison to be made. Of the 46 nachs examined in spring 15 (33%) were empty, while in summer all the 35 stomachs collected ained food. This may indicate a more extensive feeding period in summer—a conclusion similar hat suggested by the group D Iceland data.

Fig. 5 compares the relative importance of the various food groups in spring and summer. formed a considerable part of the diet in spring, Ammodytes and gadoids being of particular importa Among the crustaceans, *Eupagurus bernhardus* occurred in considerable quantities. In summer, crusta particularly Eupagurus formed a greater proportion of the diet. Portunus, Munida, and Hyas occurred in significant volumes.

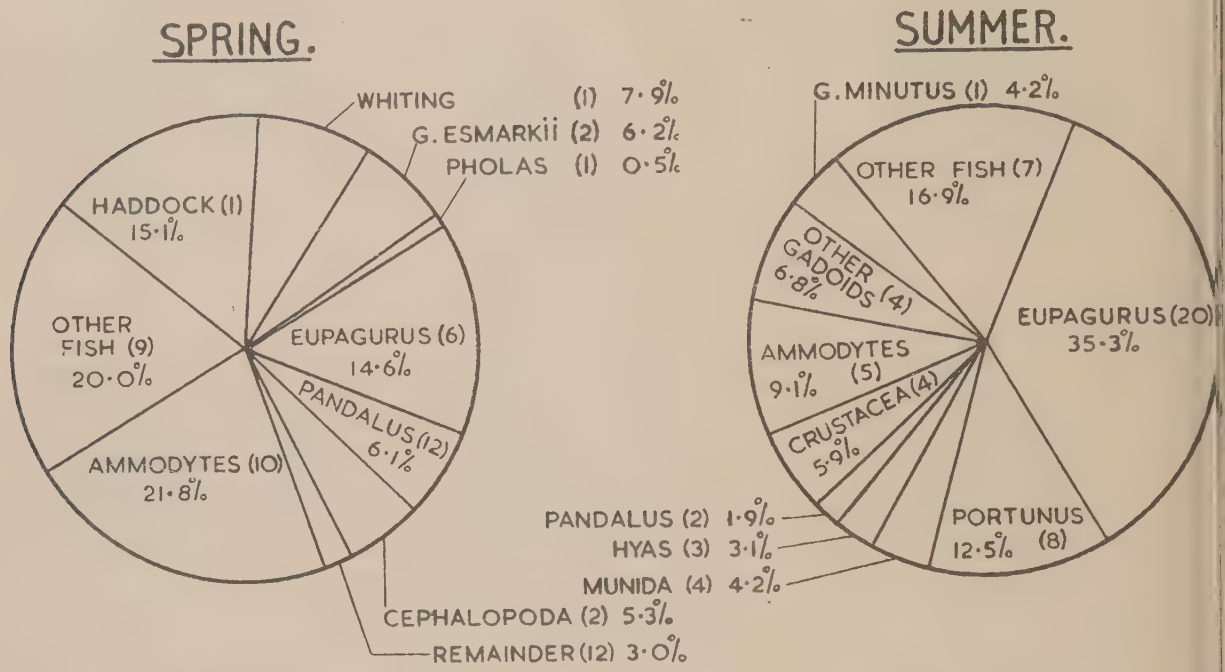


Fig. 5—Seasonal changes in the stomach contents of Faroe halibut of size group B (31-60 cms.). The volumes of the va constituents of the diet are expressed as percentages of the total food volume in spring (left) and summer (right). The nu of stomachs in which each food group occurred is shown in brackets.

COMPARISON OF FEEDING OFF FAROE AND ICELAND

Fairly large samples of group C stomachs were obtained from Faroe and Iceland during spri and this material may be used to compare the feeding in the two areas. The mean percentage of em stomachs per sample was $43{\cdot}8 \pm 6{\cdot}8\%$ at Faroe and $82{\cdot}9 \pm 8{\cdot}8\%$ at Iceland, and the difference appe to be highly significant. The Faroe samples were taken from shallower and warmer water, which m account for the more intensive feeding.

At Iceland 79·3% of the stomach contents by volume consisted of herring and *Sebastes mari* while the remaining 20·7% was almost entirely *Nephrops norvegicus*. At Faroe fish were less import accounting for only 47·8% of the total food volume. Herring, haddock, and *Sebastes marinus* were commonest fish species identified. Crustacea (with Munida and *Lithodes maia* dominant) represen 32·4% and cephalopods, although not found in the stomachs from Iceland, formed 19·5% of the f volume from Faroe.

THE FOOD OF HALIBUT FROM OTHER AREAS

West Coast of Scotland

From this area 64 stomachs were collected during two voyages by commercial line vessels, an stomachs in two hauls by the research ships. The details of the hauls are given in Table III.

TABLE III

The dates and positions of voyages and the number of stomachs collected from the west coast of Scotland.

Date	Position	Total No. of stomachs	Number containing food
April 1949	WW16b	22	11
June 1949	WW17d	42	13
August 1950	YY17d	1	1
August 1950	VV12b	1	1
	Total =	66	26

Twenty-seven of the stomachs belonged to size group C, and only five contained food, the total me of which was 3·3 ccs. This consisted entirely of fish fragments, the only identifiable material gs scales of *Argentina spp.*, found in one stomach.

The remaining 39 stomachs belonged to group D, and 21 contained food. Fish, occurring in 15 of stomachs, constituted 90·4% of the total food volume, herring and haddock being the commonest ies. *Moschites cirrosa*, which accounted for 8·6% of the volume, occurred in three stomachs, and acean fragments present in two stomachs made up the remaining 1%.

TH SEA

Thirteen stomachs, six in group B and seven in group C were collected from the North Sea in 12 l hauls by *Explorer*. The details of the hauls are given in Table IV.

TABLE IV

The dates and positions from which stomachs were collected in the North Sea.

Size group	Date	Position
B	March 1949	C 20 c
	April 1949	E 18 a
	April 1949	D 19 a
	May 1950	F 20 a
	October 1950	G 14 a
	October 1950	H 13 b
C	March 1949	G 20 c
	April 1950	A 17 d
	July 1950	C 14 d
	November 1950	C 21 d
	July 1951	E 21 c
	July 1951	C 14 d
	July 1951	F 18 a

All the stomachs in group B contained food, and the total volume was made up of 94·6% fish 5·4% crustacea. The percentages which the various species formed of the total food volume, with number of occurrences in brackets, are as follows:—

FISH			CRUSTACEA		
Gadus merlangus	44·74%	(1)	*Eupagurus bernhardus*	5·07%	(1)
Gadus aeglifinus	24·45%	(1)	Crustacean remains	0·37%	(1)
Gadus minutus	0·46%	(1)			
Fish remains	24·91%	(2)			

All but one of the seven stomachs in group C contained food. Fish, mostly whiting and hadd formed 91·7% of the total volume, and cephalopoda (*Moschites cirrosa*) accounted for 8·2%

The number of stomachs examined from the North Sea is small, but their contents suggest fish is the most important constituent of the diet, and this confirms unpublished work of Dr. B. B. who examined 50 halibut stomachs from the North Sea, and found fish present in 23, crustacea in and cephalopoda in 5.

Newfoundland

Five halibut stomachs were collected from the experimental trawler *Fairfree* while fishing at south end of Grand Bank in June, 1950. The stomachs were from large fish (size group D) and all well filled. All contained fish, the volumes being -sand dab (*Hippoglossus platessoides*) 550 ccs., had 510 ccs., pollack (*Gadus pollachius*) 270 ccs., Sebastes sp. 140 ccs., and gadoid 130 ccs.

FEEDING VARIATIONS WITH AGE

In comparing the food of the various age groups of halibut it must be remembered that large small halibut seldom inhabit the same grounds, and that the former are caught mostly by lining and latter by trawling. In spite of the bias which may be caused by these ground and gear differen it is still useful to compare the food of the various age groups.

It has been shown (p. 6) that the diet of group A fish at Iceland contains a large proportio crustacea, and that in size group B, although crustacea are still present, fish predominates. The sam in both groups were taken by trawl. The two larger size groups at Iceland were all caught by line, there is no significant difference between areas. Only data collected in the same months are consid in order to obviate seasonal differences. The winter diet of group C fish at Iceland consisted of 53 crustacea and 42·4% fish by volume, while in size group D, crustacea accounted for only 13·6% food, and the percentage of fish had risen to 84·5%. In spring the group C diet was 79·3% fish 20·7% crustacea, while group D stomachs contained almost entirely (99·8%) fish.

In the samples (taken by lines) from the west coast of Scotland, group C specimens had been fee entirely on fish, and group D stomachs contained 90% fish, 9% cephalopod and 1% crustacea. In North Sea samples (which were all trawled) the group B stomachs contained 95% fish and 5% crusta and group C, 92% fish and 8% cephalopod. At Newfoundland, where again trawl was the only used, all five specimens (of size group D) contained fish alone.

Thus, considering the stomach contents from all the above areas, it appears that while crust and fish are of importance in the smaller size groups, the older specimens depend almost entirely on

This is not so at Faroe, however. Sufficient samples have been collected in spring from size gro B, C and D to allow of a comparison between these groups without bias due to seasonal differen

percentages which each of the three main food groups formed of the total food volume were as ws:—

	Group B	Group C	Group D
Fish	72·0%	47·7%	41·1%
Crustacea	22·9%	32·4%	34·1%
Cephalopoda	5·2%	19·5%	24·6%

There is little difference in diet between the two larger size categories. The smaller specimens ain a considerably higher proportion of fish due chiefly to their intensive feeding on Ammodytes.

DISCUSSION

The proportions of food groups in the stomach of a fish do not necessarily indicate the proportions hich the groups were eaten, or their relative values as food to the fish. To ascertain the effective e of each food group in the diet, some knowledge of the rates of digestion and relative nutritive es of the various groups is required. Such knowledge is particularly necessary when the diet is varied includes many different types of organisms. In the North Sea haddock, for example, Ritchie (1932) d as many as 188 species in the stomachs, and stated that in areas where the population of food ials is not rich in individuals, as many as 22 species may be found in one sample of stomachs. Homans Needler (1944) found that the haddock of the North-west Atlantic also was a very catholic feeder, than 200 species being eaten. Even in the cod, Brown and Cheng (1946) found 73 species in achs from Bear Island, and in lemon soles from Faroe, Rae (1939) found 54 species. In these fish, use of the varied diet, there arises the difficulty of determining the relative values of the food groups. ıe case of the halibut, however, only 33 species have been found in the stomachs. These are listed ollows:—

Fish	15 species
Crustacea	13 species
Cephalopoda	2 species
Gastropoda	1 species
Asteroid	1 species
Bryozoa	1 species

In general, then, the number of organisms which serve as food for the halibut is limited, and when icular areas and size groups are considered, the number may be very small indeed. Thus the large out found off Iceland were feeding on only eleven species of organisms, and a single species of fish, *stes marinus*, constituted over 75% of the food volume. It is therefore reasonable to believe, even out knowledge of digestion rates and nutritive values, that in this population, at least, fish (and icularly *Sebastes marinus*) is of paramount importance in the diet.

Tåning (1949) has suggested that Sebastes, which is not yet fished systematically by most countries, come to be of great direct importance as human food. The present observations indicate that stes is already of considerable indirect importance, since the halibut population at Iceland, which ears to depend on Sebastes for its main source of food, is the basis of a great commercial long-line ry. It seems that Sebastes may play a role in the life-history of the halibut comparable to that of

capelin and herring in the life-history of the cod, and of Ammodytes in the life-history of many sm fish.

In discussing the importance of Sebastes in the food of the halibut, it is instructive to consider w food is available to fish of such great size. Elton (1926) points out that there is an optimum size of for each animal, and that without some special feeding mechanism, it is not feasible for an animal to on organisms which are very small in proportion to its own size. It has been shown by various wo (see Ritchie on haddock and Rae on lemon soles, already quoted) that as a fish increases in size it i on progressively larger organisms. It would be expected, therefore, that for a fish as large as a ma halibut, the food organisms themselves must be large, or, if smaller, must be present in sufficient nun to make their capture easy.

Thompson (1943) states that large cod could not subsist on the small crustaceans of the lin inshore areas, and suggests that it is the demand for suitable large food that controls the increasi great migrations of the cod as it grows. The movements of halibut also may be connected, to s extent at least, with food. It is known that young halibut move out from the coastal waters as grow, and unpublished observations by the writer indicate a considerable size difference between hal caught near the 100 fathom line, and those caught deeper than 200 fathoms. This movement shoul considered along with the changes in food with age noted previously (p. 16). It is probable that a fish grows, the small organisms of the coastal waters are no longer sufficient as food, so that crusta with two exceptions, begin to disappear from the diet. One of these exceptions is *Nephrops norveg* which is not large, but when available it is usually present in considerable numbers, and thus ever largest halibut may subsist on it at certain times of the year. The other exception, *Lithodes maia*, g to a considerable size, and the stomach of a six-foot halibut has been found completely filled by *Lithodes*. Apart from Nephrops and Lithodes, however, adult halibut apparently demand food orga large in size or rich in abundance, and find them in deep waters where *Sebastes marinus* is abun The correspondence between the distributions of Sebastes and the halibut is of interest. Thom and van Cleve (1936) give the limiting temperature range for halibut as 3°-8°C, and Tåning s that *Sebastes marinus* requires temperatures between 3° and 8·5°C for breeding.

From the knowledge that Sebastes forms such an important part of the halibut's food, it ma possible to deduce details of the halibut's feeding habits. Boldevsky (1944), working on the foo Sebastes in the Barents Sea, reported that the role of the benthos was almost insignificant. This sug that Sebastes takes its food from above the bottom. It seems probable, therefore, that the halibut must leave the bottom in pursuit of its prey. This conclusion is supported by the work of Suy (1934) who states that the halibut of the North Pacific feeds not only on benthos but also on a animals living on or above the bottom. Further information on the feeding habits can be derived observations made by the writer during two cruises on commercial long-line vessels. On the first c Sebastes was caught in fair numbers, but on the second cruise it was relatively scarce, and tusk ling were more abundant. Stomachs collected from each cruise, however, showed that on both occa halibut had been feeding almost exclusively on Sebastes, which formed over 95% of the food volu This would seem to indicate selective feeding on the part of the halibut.

It may be possible to link the present work with previous biochemical investigations. Lo *et al.* (1933) studied the vitamin A content of halibut liver oil. They showed that the vitamin A po increased with size of liver and of fish, and that the content was greater in fish from northern w In trying to account for these facts, Lovern and Sharp (1933) concluded that no significance coul attached to stomach contents. But their data on the food were very limited. The authors considered halibut "ate anything they could get" and they failed to discover any change in the diet with age. the present paper, such a change is suggested (p. 16) and the great predominance of *Sebastes ma* in the diet of older fish from northern waters is noted. Tåning (1949) states that Sebastes is ric vitamin A, and that Sebastes-liver oil has a higher vitamin A content than cod-liver oil. This is suppo by recent Canadian work (Annual Report of the Fisheries Research Board of Canada, 1952) w indicates that Sebastes waste yields high vitamin A values, and Sebastes-liver oil very high values. thus seems possible that the richness of halibut-liver oil, and the changes which take place in its vita A content with growth may be influenced by the diet of the fish.

Since baited lines are used extensively in the commercial halibut fishery, catches may depend on factors which affect feeding. Water temperatures, and changes in the physiology of the fish due to wning, may influence the feeding and thus indirectly the commercial catch. Experimental work ıthaway, 1927) has shown that fish consumed three times as much food at 20°C as at 10°C, and that osure to the lower temperature for a week did not bring about acclimitization, but rather tended to ress the food consumption further. Such reduced feeding, due probably to low temperatures, has n noted in the sea. Blegvad (1916) stated that flatfish seemed to feed little in winter, and Rae (1939) orted that lemon soles in Scottish waters took little or no food in December, but that feeding intensity reafter increased, reaching a peak in summer. The same probably holds for halibut, and data in present paper suggest that feeding intensity in summer is higher than in spring although this may be entirely due to temperature. Devold (1938) stated that most ripe halibut caught in nets had ɔty stomachs, and concluded that halibut fed little during the spawning season.

It would therefore be expected that the best catches would be made in summer or early autumn, ɛn spawning is over and temperatures are high. Yet the statistics of the Aberdeen halibut fishery w that the highest catches per 100 lines are usually made from March to May, before the maximum peratures occur, and during what is probably the spawning season. Why should the best catches made by lines at a time when the feeding intensity is low? The answer may be that even although a small proportion of the population is feeding, a high concentration of fish in a small area, such robably exists during spawning, would give the maximum chance of a good catch. Again it has ɑ noted by various authors (see for example Wilson, 1894, and Lloyd and Yonge, p. 364, 1947) that regation of individuals causes accelerated feeding, and that a tightly packed shoal of fish would ɔably feed more vigorously than widely dispersed individuals. This effect may help to compensate ɑ "disinclination" of the fish to feed. It is also of interest to consider the possibility that a 'non-feeding" may sometimes take bait. This situation is somewhat similar to a salmon's taking bait in fresh er. It is known that salmon do not, probably cannot, feed normally in fresh water, yet they are n by anglers on flies and lures. In seeking to explain this, Waddington (1947) puts forward a ulative theory that changes in environmental conditions may produce an increased irritability, that the presentation of bait to a restive fish elicits the feeding behaviour pattern, which results in fish taking bait. If this applied to the halibut, we could assume that a non-feeding fish might snap od in its vicinity, but would not pass the food into the stomach. This might account for the empty achs of some fish which had taken bait.

SUMMARY

A description is given of the food of the North Atlantic halibut, based on the examination of 1,225 stomachs, mostly from the waters round Iceland and Faroe.

The halibut had been feeding mainly on fish, decapod crustacea, and cephalopoda.

A change in feeding with age, from a more or less mixed diet in the younger specimens to an almost entirely fish diet in the adults is suggested, particularly off Iceland.

The feeding intensity is greater in summer than in spring.

The small number of species required to support the halibut population is noted, and the importance of *Sebastes marinus* discussed.

The feeding habits are considered and some of the factors connected with a fish taking bait are discussed.

REFERENCES

BLEGVAD, H. (1916) "On the food of fishes in the Danish waters within the Skaw." Rep. Danish biol. Sta., XXIV, pp. 17-72.

BOGOROV, B. G., MANTEUFEL, B. P., and PAVLOVA, A. E. (1939) "Nutrition of the small sand-eel (*Ammodytes tobianus*) in Murman waters." Trans. Inst. Mar. Fish. U.S.S.R., Vol. IV.

BOLDOVSKY, G. V. (1944) "The Food of the Norway haddock in the Barents Sea." Trans. Knipovich polyar. sci. Inst., Vol. VIII.

BROWN, W. W., and CHENG, C. (1946) "Investigations into the food of the cod (*Gadus Calliarias* L.) off Bear Island, and c cod and haddock (*G. aeglefinus* L.) off Iceland and the Murman Coast." Hull Bull. Mar. Ecol., Vol. III, No. 18.

DEVOLD, F. (1938) "The North Atlantic halibut and net fishing." Rep. Norweg. Fish. Invest., Vol. V, No. 6.

ELTON, C. (1926) "Animal ecology." London, Sedgwick and Jackson.

FISHERIES RESEARCH BOARD OF CANADA (1952) Annual Report (for year 1951).

HARDY, A. C. (1924) "The Herring in relation to its animate environment. Part I. The Food and fe habits of the herring with special reference to the west coast of England." Fish. Invest., Lond. Ser. II, Vol. VII, No. 3.

HATHAWAY, E. S. (1927) "The Relation of temperature to the quantity of food consumed by fishes." Ecology, Vol. VIII, No. 4, pp. 428-434.

HYNES, H. B. N. (1950) "The Food of freshwater sticklebacks (*Gasterosteus aculeatus and Pygosteus pungitius*), a review of methods used in studies of the food of fishes." J. Anim. Ecol., Vol. 19. No. 1, pp. 36-58.

HOMANS, R. E. S., and NEEDLER, A. W. H. (1944) "The Food of the Haddock." Proc. N.S. Inst. Sci., Vol. XXI, pts. 1 and 2.

JESPERSEN, P. (1926) "On the halibut in Icelandic waters." Rapp. Cons. Explor. Mer. Vol. XXXIX, pp. 103-113.

LLOYD, A. J., and YONGE, C. M. (1947) "The Biology of *Crangon vulgaris* L. in the Bristol Channel and Severn Estuary." J. Mar. biol. Ass. U.K. Vol. XXVI, No. 4, pp. 626-661.

LOVERN, J. A., and SHARP, J. G. (1933) "The Diet of the halibut and intensity of feeding in relation to the vitamin A po of the liver oil." Biochem. J., Vol. XXVII, pp. 1470-1472.

LOVERN, J. A., EDISBURY, J. R., and MORTON, R. A. (1933) "Variation in Vitamin A content of fish liver oils, with particular reference to sea fluctuations in the potency of halibut-liver oil." Biochem. J., Vol. XXVII, pp. 1461-1469.

RAE, B. B. (*unpublished*) "Notes on the food of turbot, brill and halibut."

Do. (1939) "The Food of lemon soles in Faroese waters." Rapp. Cons. Explor. Mer, Vol. CIX

RITCHIE, A. (1932) "The Food and feeding habits of the haddock." Rapp. Cons. Explor. Mer, Vol. LXXX, pp. 16-19.

SCOTT, T. (1910) "On the food of the halibut, with notes on the food of *Scorpaena, Phycis blennoides* garpike, and *Chimaera monstrosa*." 28th Rep. Fish. Bd. Scot. (1909), pt. III, pp. 24-37.

SUYEHIRO, Y. (1934) "Studies on the digestive system and the feeding habit of the important fishes o North Pacific.
II. The plaice, *Lepidopsetta mochigarei* Snyder and the halibut, *Hippoglossoides ela* Jordan and Gilbert."
Bull. Jap. Soc. sci. Fish., Vol. 3, No. 2, pp. 65-72.

TÅNING, A. V. (1949) "On the breeding places and abundance of the red fish (Sebastes) in the North Atl J. Cons. int. Explor. Mer, Vol. XVI, No. 1, pp. 85-95.

THOMPSON, W. F., and VAN CLEVE, R. (1936) "The Life history of the Pacific halibut. (2) Distribution and early life History." Rep. int. Fish. Comm., No. 9, Seattle.

THOMPSON, H. (1943) "A Biological and economic study of cod in the Newfoundland area." Res. Bull. Div. Fish. Resour. Newfoundld., No. 14.

TODD, R. A. (1905) "Report on the food of fishes collected during 1902." Mar. biol. Ass. U.K., Rep. fish. hydrogr. Invest. North Sea, 1902-1903. Cd. 2 pp. 227-287.

WADDINGTON, R. (1947) "Salmon fishing. A new philosophy." London, Peter Davies.

WILSON, G. (1894) "Notes on how fish find food." 63rd Rep. Brit. Ass (1893). pp. 548-551.

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